THE AMERICAN MINERALOGIST
JOURNAL OF THE MINERALOGICAL SOCIETY OF AMERICA

Vol. 12 SEPTEMBER, 1927 No. 9

AN X-RAY STUDY OF THE GARNET GROUP

C. H. Stockwell, *University of Wisconsin.*

ABSTRACT

W. E. Ford has found that if the index and specific gravity of a garnet are known, together with its chief components as determined by qualitative tests, it ought to be possible in the majority of cases to predict rather closely what its chemical composition should be.

A. N. Winchell finds that if the index of a garnet together with either its specific gravity or isotropic or anisotropic character are known then the approximate composition of any garnet can be determined. A qualitative test for manganese is necessary in order to distinguish spessartite from almandite.

From the following X-ray study of the garnet group it is concluded that by X-ray analysis alone (together with a simple test for manganese) any garnet may be easily determined just as closely as by Winchell's method. It is also found that if the X-ray data, index of refraction, and specific gravity are known for any garnet then it may be determined, at least in many cases, probably just as accurately as by Ford's method and no chemical tests, other than for manganese, are necessary.

The determination of the relationships between the physical properties and the chemical composition of minerals is an important problem which has received the attention of many mineralogists. Up to a short time ago, however, the only physical properties usually studied were the optical properties and the specific gravity. Within recent years X-ray analysis[1] has furnished an additional and independent physical method for studying minerals. In a study of an isomorphous group like the garnet group it gives information of two kinds both of which are variable and depend on the chemical composition; one of these is the size of the unit cube and the other is the intensities of lines on the X-ray pattern.

The relationships between the index of refraction, specific gravity, and the chemical composition of the garnet group have already been studied in considerable detail, particularly by W. E. Ford.[2]

---

[1] The Structure of Crystals. Ralph W. G. Wyckoff. Chemical Catalogue Co., New York, 1924. X-rays and Crystal Structure. W. H. Bragg and W. L. Bragg, G. Bell and Sons Ltd., London, 1925.

[2] A study of the Relations existing between the chemical, optical and other physical Properties of the Members of the Garnet Group. *Amer. Jour. Sci.,* 4th Series, vol. **XL**, pp. 33–49 (1915).

From a study of nearly two hundred analyses of garnets containing only the five common molecules, pyrope, grossularite, spessartite, almandite, and andradite, he found that nearly 15% contained four or more constituents, with the molecule in smallest amount forming more than 5% of the total. The remaining 85% were garnets in which two or three components formed more than 95% of the total. Nearly 17% of all the analyses studied had only two constituents. In addition he concluded that in any given system formed by the mixture of three garnet molecules, two of them must predominate while the third is present in very subordinate amounts. A study was also made on 23 analyzed garnets of known index of refraction and on 64 analyzed garnets of known specific gravity and the relationships between chemical composition, index of refraction and specific gravity were determined. These relationships were plotted in the form of equilateral triangular graphs and it was concluded that if the refractive index and specific gravity of a garnet are known, together with its chief components as determined by qualitative tests, it ought to be possible in the majority of cases to predict rather closely what the chemical composition should be. He calculated that the indices and specific gravities of the five common garnets are as given in the accompanying table opposite the name of the garnet.

Boeke[3] has shown that the miscibility of different garnets with each other has definite limits.

Ford's triangular diagrams show complete miscibility between grossularite-andradite, pyrope-almandite, and spessartite-almandite, but only a limited miscibility[4] of grossularite-andradite with almandite, pyrope, and spessartite. Thus there is evidence that the garnets are divisible into two groups, one group comprising grossularite and andradite and the other group comprising pyrope, almandite and spessartite. These two groups are incompletely isomorphous with one another, the miscibility of one in the other having a maximum of 25 per cent. With the apparent exception of pyrope and spessartite, the garnets in each of the two groups are completely isomorphous with one another. This division of the garnets into two groups, although shown by Ford's data, was apparently not recognized by him.

[3] *Zeit. Krys.*, **LIII**, p. 149 (1914).

[4] Pyrope and spessartite also seem to be incompletely miscible with one another.

Winchell[5] has recognized the probability of this two-divisional grouping of the garnets. He has plotted indices of refraction as ordinates and specific gravities as abcissæ, thus producing a diagram which clearly shows this relationship. He finds that garnets belonging to the grossularite-andradite group are usually anisotropic while those belonging to the other group are usually isotropic and points out that this fact together with the index of refraction serves to determine the approximate composition of any garnet by means of the diagram. In place of this method based wholly on optic properties, the index of refraction and specific gravity serve the same purpose when the diagram is used.

These are the first methods ever proposed for the determination of garnets by purely physical means. They have certain limitations, however, which may be pointed out. Thus in general a garnet composed dominantly of the almandite molecule can not be distinguished from one composed dominantly of the spessartite molecule and *vice versa*. To distinguish these from one another a qualitative test for manganese must be made. These methods also have limitations due to the fact that the points for pure grossularite and pure pyrope lie close together. Thus andradite containing pyrope in amounts up to the limits of its miscibility in andradite (say 25%) cannot be distinguished from andradite containing similar amounts of grossularite. Likewise almandite or spessartite containing up to about 25% grossularite cannot be distinguished from almandite or spessartite containing up to about 25% pyrope. In these cases however the dominant molecule can be determined.

In summary it seems well established that the chemical composition of the majority of garnets can be determined rather closely if the refractive index and specific gravity are known together with the chief bases as determined by qualitative tests; also that the composition may be determined less accurately, but yet close enough for many purposes, if the index of refraction and specific gravity (or isotropic or anisotropic character) only are known and no chemical tests are required excepting for, in some instances, a simple test for manganese.

Garnets have already been studied by X-ray methods by two investigators. Shoji Nishikawa,[6] investigated an almandite in which about one third of the iron is replaced by manganese. He found that it has a body-centered cubic lattice; the length of the edge of the unit cube is 11.4 Å; there are eight molecules in the unit cube; and the space group is Oi-10.[7]

---

[5] Optical Mineralogy, Part II, *in press*.

[6] Crystal Structure of a Garnet. *Tokyo Math. Phys. Soc.*, Series 2., vol. 9, 1917–18, 194–197.

G. Menzer[8] studied a nearly pure calcium garnet from Xalostoc, Mexico. He confirmed the conclusions of Nishikawa and determined the arrangement of the atoms in more detail. For this garnet he found the length of the edge of the unit cube to be 11.80 ± .06 Å.

The same investigator[9] later determined the edge of the unit cube for each of the garnets, pyrope, almandite, spessartite, grossularite, uvarovite and andradite. In each case, except for pyrope, especially pure garnets are said to have been studied, mixtures with other garnet molecules being very slight. No pure pyrope is known so a Mg-rich garnet containing some ferrous iron was studied. He also calculated the specific gravities and compared them with the specific gravities as given in the literature, the latter having been obtained by direct measurement by the usual methods. The determination of the length of the edge of the unit cube was made in two different ways, with results as follows:

	I	II
Pyrope (Mg, Fe)	11.514 ± 0.021Å	11.510 ± 0.009Å
Almandite	11.515 ± 0.031	11.497 ± 0.010
Spessartite	11.611 ± 0.022	11.602 ± 0.011
Grossularite	11.838 ± 0.022	11.833 ± 0.011
Uvarovite	11.977 ± 0.027	11.951 ± 0.011
Andradite	12.044 ± 0.030	12.024 ± 0.012

The calculated specific gravities and those given in the literature are:

	I	II	Literature
Pyrope	3.729 ± 0.04	3.733 ± 0.015	3.710; 3.679
Almandite	4.333 ± 0.04	4.354 ± 0.02	4.1 — 4.3
Sepssartite	4.189 ± 0.03	4.198 ± 0.02	4.0586
Grossularite	3.613 ± 0.03	3.618 ± 0.02	3.506
Uvarovite	3.832 ± 0.03	3.858 ± 0.02	3.772
Andradite	3.856 ± 0.04	3.875 ± 0.02	3.8 ±

---

[7] See Wyckoff: *op. cit.*

[8] Die Kristall struktur von Granat. *Cent. Min.*, Abt. A, 1925, pp. 344–345.

[9] Die Gitterkonstanten der Granate. *Cent. Min.*, Abt. A, pp. 343–344 (1926).

It is observed that the calculated values of specific gravities are somewhat higher than those obtained by direct determination. The reason for this according to Menzer is that cracks and inclusions in the garnets cause specific gravity values to be too low when determined by usual methods.

The following study of the garnet group is confined to the five common members, pyrope, almandite, spessartite, grossularite, and andradite. Forty different specimens were studied. Most of these are garnets which were readily obtainable in the museum and laboratories of the Department of Geology, University of Wisconsin, and are unanalyzed material. In only two cases (Nos. 9 and 20) was original material of analyzed garnets obtained; these garnets were kindly supplied by Professor Ford of Yale University.

Since original analyzed material was not available, except in two cases, the composition of most of the remainder was determined by means of measurement of index and specific gravity together with a simple test for manganese. As already mentioned this is a means of determining at least the dominant constituents.

The presence or absence of manganese (and at the same time the presence or absence of iron) was determined by means of the borax bead before the blowpipe in both oxidizing and reducing flames. The indices of refraction of most of the garnets were determined by means of immersion liquids[10] of maximum index equal to 1.870, the set of liquids differing from one another by .01 in index. The indices of a few of the garnets and also of the set of immersion liquids were measured by the method of total reflection by the use of a hemisphere of high index glass mounted on a Federoff universal stage as described by Nakashima.[11] The indices of two of the garnets of index greater than 1.870 were determined by the method of minimum deviation. The specific gravities were determined by means of heavy solution (Clerici solution) and a Westphal balance. The results of these determinations are tabulated in the accompanying table, where different garnets are grouped according to the dominant constituents as determined by the above method.[12] The results are expressed graphically in Figure 1. The positions of the pure molecules, represented by a dot in the center of a large circle, were plotted from Ford's data. The small circles represent garnets without manganese and the triangles represent those with manganese as determined by the blowpipe test. The broken lines show the limits of miscibility of the two groups. This diagram alone seems to indicate that the miscibility is almost complete, but diagrams on X-ray data, as given farther on, show a wider separation between the two groups. This diagram, due to the limited number of determinations, also does not show complete miscibility between the members of one group, but that such a miscibility does exist has already been well established.

---

[10] Mixtures of methylene iodide, iodoform, sulphur, SnI_4, AsI_3, SbI_3. See Larsen: "Microscopic Determination of the Nonopaque Minerals," *U.S.G.S. Bull.* **679**, p. 15 (1921).

[11] *Jour. Geol.* Vol **XXXIV**, p. 237 (1926). The method used by the writer is similar to the one described in this article except that an empirical curve between angle of total reflection and index was used as it was considered more reliable than a calculated curve. The empirical curve was obtained by the use of liquids and glasses of known index. Measurements of index by this method are considered to be accurate within ±.002.

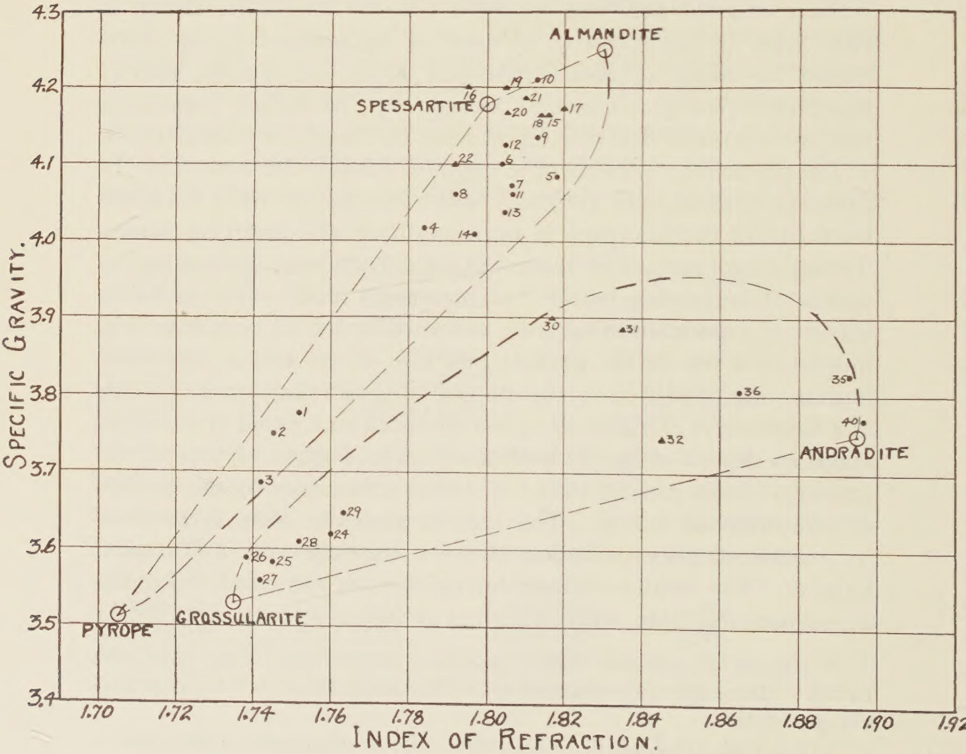


FIG. 1

---

[12] Nos. 23 and 34 were too impure or porous to permit gravity determinations so these were determined by the X-ray method.

X-ray photographs were taken of each of these garnets by means of the powder method. The apparatus used was made by the General Electric Company.[13] The X-ray tube was the Coolidge water-cooled type with a molybdenum target.

The length of edge of the unit cube was determined in each case and the results are given in the table. Special care was taken in the determination of this length for garnets numbers 9 and 20 which are original analyzed material of almandite and spessartite, respectively, and for numbers 3, 27, and 40 which Figure 1 indicates to be the purest pyrope, grossularite and andradite; respectively. In these cases the powdered garnet was mixed with sodium chloride as recommended by Wyckoff[14] for accurate determination. Measurement of the lines was done in a metal scale (supplied with the X-ray apparatus) which is graduated so that any line on the film may be directly interpreted in terms of the distance between the planes of atoms which produced the line. The film was placed in the scale so that the sodium chloride lines which are accurately known, gave the correct reading and then the readings were taken for the garnet lines. For each garnet several lines (from 8 to 12 in number in different cases) were carefully read and the significance of each in terms of the indices of the plane of atoms which produced the line were determined by equation 15a[15] or more easily by a graphical method.[16] A value for the length of the edge of the unit cube was then calculated by means of the same equation from the measurement of each of these lines. The simple average of these determinations was taken to be most nearly correct. The maximum deviation from the average in any case was .02; a more usual deviation was closer to .01. It is considered that the value given for the edge of the unit cube for these garnets is accurate within ±.01. Although a few of the remaining garnets were also accurately determined in this way most of them were not standardized with sodium chloride, but corrections which seemed reasonable, were applied, and the average of only two or three lines was taken as the final value. The values given for these garnets are less accurate, but in most cases are probably correct within ±.02.

[13] A New X-ray Diffraction Apparatus. Wheeler P. Davey: *General Electric Review*, Sept. 1922.

[14] *Op. cit.* p. 179.

[15] Wyckoff, *op. cit.* p. 187.

[16] Wheeler P. Davey, *General Electric Review*, Sept., 1922.

An attempt was then made to calculate what the length of the edge of the unit cube would be for each of the five pure end members of the garnet group. These values cannot be determined by direct measurement, since none of the members occur without at least a small amount of other garnet molecules present in isomorphous mixture. In these calculations it was assumed that in garnets consisting of mixtures of two members the size of the space lattice varies between the sizes of each of the two members in a straight line relationship with the percentage of each member present. This probably is very nearly true over the short distances involved in the calculations. At first values which were evidently very nearly correct could be assigned to each member. The two analyzed specimens (numbers 9 and 20) and one (number 27), which no doubt corresponds closely in composition to a similar garnet of which analyses have been published, were corrected on the above assumption for the small amounts of other members which they contain. No analyzed andradite was studied but number 40 is apparently very nearly pure. Garnet number 1 (pyrope) indicates that pure pyrope has a unit cube at least as small as that of this garnet. The calculated and estimated values of the length of the unit cube of the five pure members are given in the table opposite the name of the member. The value for pyrope may be only approximately correct, but the values for the other members are considered to be accurate within ±.01. These values for the unit cubes of almandite, grossularite, and andradite check very well with those determined by Menzer and listed above. There is a considerable difference in the two determinations of spessartite, the value obtained here being considerably lower than that of Menzer. The values for pyrope are of course also different because his value is for an iron-bearing pyrope.

Specific gravities were calculated from the values of the unit cubes of the pure members as well as from the values for numbers 7, 9, 20, and 27 of which the X-rayed specimen was either on original analyzed material or on material which is very similar to and from the same locality as analyzed material.

In these calculations the mass of one unit of molecular weight is taken to be 1.650×10^{-24} grams. The results are shown in column one. The specific gravities of the pure molecules as calculated by Ford are listed in column two, and those obtained by direct measurement in column three. Differences are shown in Column four.

	I	II	III	IV
Pyrope	3.571	3.510		.061
Almandite	4.332	4.250		.082
Spessartite	4.229	4.180		.049
Grossularite	3.598	3.530		.068
Andradite	3.882	3.750		.132
No. 7 Almandite	4.156		4.071	.085
No. 9 Almandite	4.236		4.135	.101
No. 20 Spessartite	4.229		4.169	.060
No. 27 Grossularite	3.607		3.558	.049

It will be noted that the specific gravities as determined by the X-ray method are uniformly higher than those determined by ordinary methods. This is in agreement with the results obtained by Menzer as previously mentioned. The differences in the values obtained are quite constant suggesting that the discrepancies may be due to some cause other than fractures or inclusions. The greatest discrepancy is between the two values for pure andradite; this indicates either that Ford's value is too low or that the estimated value of the length of the unit cube for pure andradite is too small. The same conclusion is indicated in Figure 3 for, assuming the presence of no unusual elements, it would be impossible for any garnet to occur above a line joining andradite with almandite (or spessartite).

Turning our attention now to the variation in the intensities of lines on the X-ray film, we find that the intensities of certain lines vary decidedly with chemical composition, but fine distinctions cannot, in general, be made, due largely to the inaccuracy in measuring intensities. The intensities of the lines of the different types of garnets are represented in Figure 4, where the length of the line is approximately proportional to intensity. All of the garnets listed as pyrope in the table have the same intensities as far as can be observed and these intensities are shown for pyrope in figure 4. Likewise all almandite and spessartite garnets listed in the table have the intensities of almandite-spessartite, figure 4. Also all grossularite garnets listed in the table have the intensities of grossularite, figure 4. Of the andradite garnets in the table only numbers 35 to 40 inclusive (the purest andradite) have intensities as shown for andradite in figure 4. Numbers 30 to 34 inclusive have intensities intermediate between andradite and almandite-spessartite or grossularite. Most of these last garnets are "Polyadelphite."

As shown in figure 4, the most distinctive feature of pyrope, as far as intensities are concerned, is that the lines from planes 332, 121 (2) (second order reflection from the 121 plane) and 150-341 are all of equal strength. This feature serves to distinguish pyrope from the other garnets. Almandite gives the same type of pattern as spessartite, but these can be distinguished from pyrope by the fact that line 332 is very faint in almandite and spessartite. The grossularite pattern is very similar to that of almandite-spessartite except that line 332 is stronger, but not so strong as for pyrope. Andradite gives a quite distinctive pattern; the most distinctive and characteristic features are that line 121 (2) is very strong, line 130 (2) is strong and line 111 (4) is very weak. All these differences are much more evident on the films themselves than on the diagrams.

This leads to the practical question of determination of unknown garnets by X-ray analysis. The difficulty of distinguishing almandite from spessartite is present here as it was also in the method of specific gravity and index determination, but the simple blowpipe test for manganese may be easily applied. Taking the two factors, intensity of lines and the size of the unit cube, into consideration it may be safely concluded that by X-ray analysis alone, except for a simple qualitative test for manganese, the dominant molecule of any garnet may be determined.

Thus garnets dominantly pyrope or almandite may have the same size of unit cube, but they can be differentiated by intensities. The difference in intensity between grossularite and almandite-spessartite is slight and they can not be safely distinguished on this basis, but there is a wide difference in the size of the unit cubes. Grossularite has, in general, the same size of unit cube as the polyadelphite variety of andradite, but these can easily be distinguished by differences in intensities. It is not certain from the available data that two constitutents each forming about 50% of the total can be determined by X-ray analysis alone, but a careful study of relative intensities of lines should make this possible. Useful conclusions of a more special nature may also be drawn such as: any garnet with a unit cube smaller than andradite contains some pyrope; likewise any garnet with a unit cube larger than that of spessartite contains some calcium garnet.

This method of determination of garnets gives just as much information as the method of index and gravity determination and the determination is much easier to make since immersion media of high index are not always available and the impure or porous nature of some garnets may make even approximate determination of the specific gravity difficult. The determination of the dominant constituent may be sufficient for many purposes.

If either or both the index of refraction and specific gravity of a garnet, together with the X-ray data, particularly the size of the unit cube, and the presence or absence of manganese, are known then its composition can be determined much more accurately than if the X-ray data alone are available. In many cases the two dominant constituents can be determined and their approximate percentages obtained and in some cases even a third may be determined, but, as Ford has shown, a third constituent is usually very minor and so it usually may be neglected.

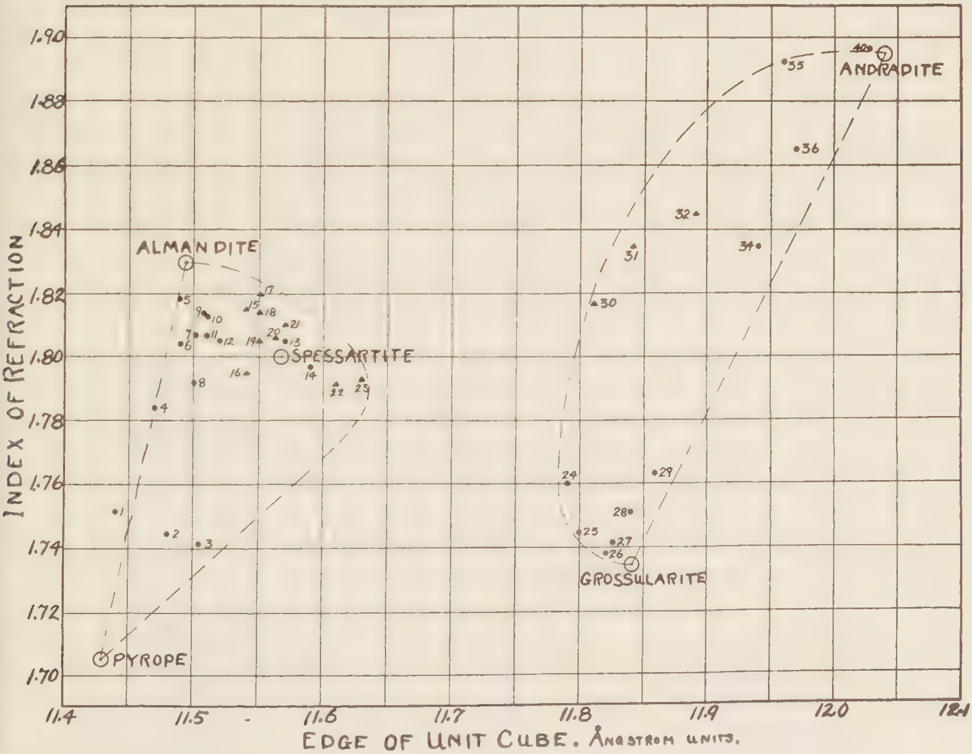


FIG. 2.

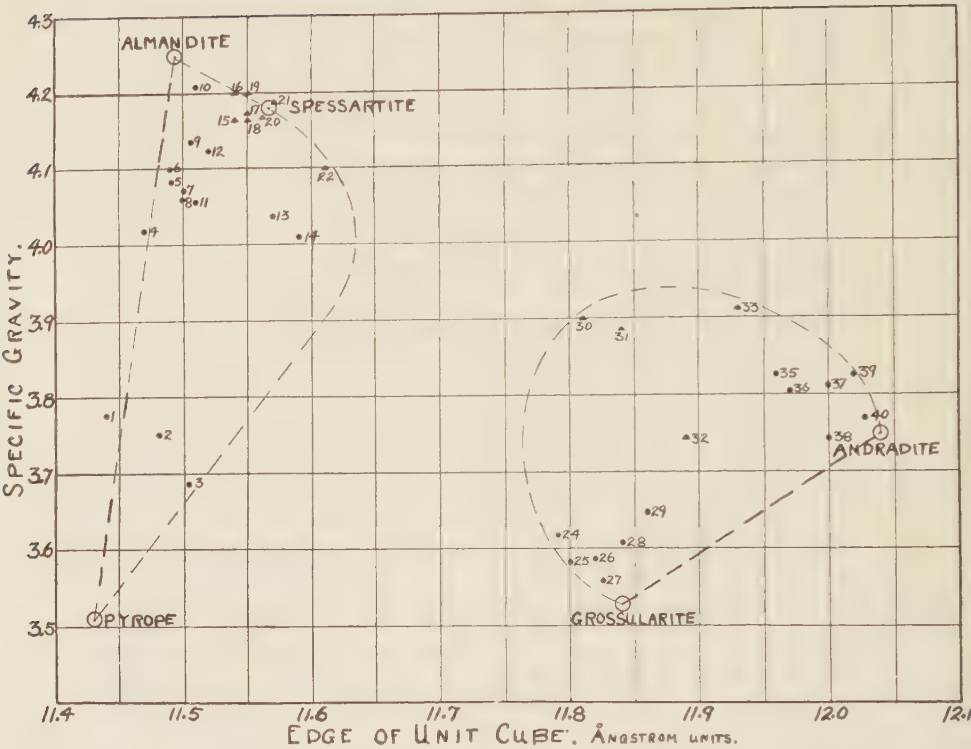


FIG. 3.

In figure 2 the indices of refraction, and in figure 3 the specific gravities, of the garnets studied are plotted against the length of the edge of the unit cubes. The positions of the pure end members are plotted from Ford's calculated indices and specific gravities and from the above calculated and estimated sizes of the unit cubes. The other symbols are as in figure 1.

A striking feature of the diagrams (figures 2 and 3) is that the two groups of garnets are here more distinctly separated. It appears to show conclusively that at least most garnets belong to one or the other group, but of course does not mean that no garnet will ever be found which is intermediate between the two groups.

That these two diagrams give more information about the chemical composition of an unknown garnet than does the index-gravity diagram alone is due largely to the fact that pyrope and grossularite are more widely separated.

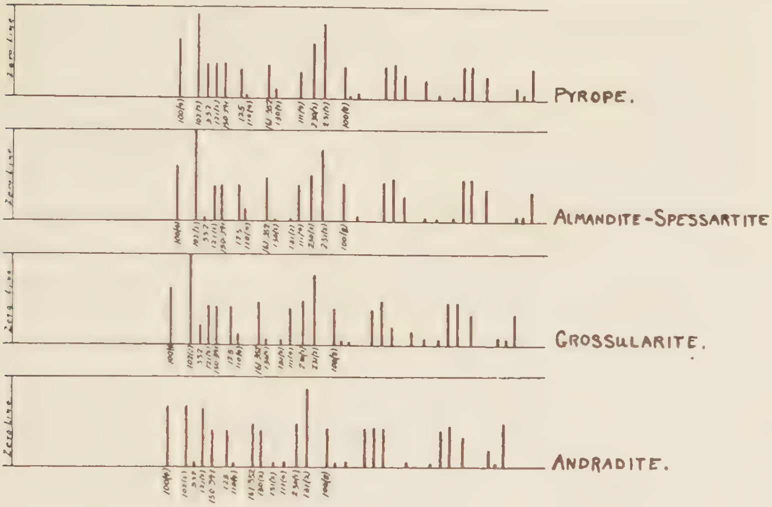


FIG. 4.

In the determination of an unknown by this method it has to be assumed for the present that the index, specific gravity, and size of unit cube depend upon chemical composition in a straight line relationship. That such is very nearly or exactly so for the index and specific gravity, at least, is shown by Ford's work.

The use of the diagrams for the determination of the percentages of two dominant constituents may be best illustrated by examples.

Garnet No. 4. The point lies close to or on the line between almandite and pyrope, therefore Ca-garnet and spessartite are eliminated as unimportant. Spessartite is also eliminated by the absence of Mn as shown by the blowpipe test. Measurement of the proportion of almandite to spessartite on each of the three diagrams gives,

Fig. 1.	Almandite	66.5%
" 2.	"	63.4
" 3.	"	69.0

Average—Almandite 66% Pyrope 34%

Garnet No. 22. Blowpipe tests indicate the presence of manganese and at the same time the absence of iron. This simplifies matters considerably as the possibilities are now limited to spessartite, pyrope and grossularite. Reference to Fig. 1 shows dominance of spessartite with some grossularite or pyrope or both. In Fig. 2, the point is practically on a line between spessartite and grossularite, therefore if pyrope is present in importance then andradite is also; but andradite is absent as shown by blowpipe test and so pyrope must also be absent (or unimportant). The garnet therefore consists of spessartite and grossularite; measurement of the proportions on the three diagrams gives an average value of spessartite 87%, grossularite 13%; maximum difference from the average is 2.5%.

Garnet No. 14. Blowpipe tests show the absence of manganese; Fig. 1 shows dominance of almandite with either pyrope or grossularite of secondary importance and probably a minor amount or absence of andradite since the point is slightly to the right of a line joining almandite and pyrope and on a line joining almandite and grossularite. In figure 2 the point is almost on a line between almandite and grossularite, thus giving two possibilities:—either grossularite is important or both andradite and pyrope are important. But andradite has been shown to be minor or absent, therefore pyrope is unimportant. Figure 3 confirms this view as the point is still nearly on the line between grossularite and almandite although the position of andradite in this diagram is quite different. The garnet therefore consists dominantly of almandite and spessartite. The measured proportions of the two give an average of almandite 68%, grossularite 32%, with a maximum difference from the mean in the two readings of 2%. In this case it was stated that the point lies approximately on the line between almandite and grossularite. As a matter of fact it lies slightly toward the pyrope side in each of the diagrams, thus indicating that pyrope is present as the minor third constituent. Supposing the accuracy of the plotted data is sufficient to really show the presence of this minor constitutent, then the percentages of the three constituents may be taken from the graph by measurements in a triangle with a corner at each of the three constituents. In figure 1 the triangle is too acute to give good results; measurements on figures 2 and 3 give results in remarkably good agreement with one another.

Fig. 1.	Almandite	67.3%	Grossularite	28.6%	Pyrope	4.2%
Fig. 2.	"	67.1%	"	28.8%	"	4.1%

Garnet No. 30. Blowpipe tests show the presence in important amounts of both manganese and iron. The intensities of lines on the X-ray film show that an important amount of andradite is present. The two major constituents are, therefore, probably andradite and spessartite. Figure 1 indicates that andradite and spessartite are present in about equal amounts, also the point lies below a line joining spessartite with andradite thus indicating a dominance over almandite of either pyrope or grossularite or both. Figure 2 shows that there is some grossularite as the point lies to the right of a line joining pyrope to andradite. Since most garnets have only three constituents it seems probable that this garnet consists of three molecules, andradite, spessartite, and grossularite. Calculation of the proportions by the triangular method gives the following values.

Fig. 1.	Andradite	32.4%	Spessartite	45.9%	Grossularite	21.4%
“ 2.	“	35.9	“	36.8	“	27.1
“ 3.	“	43.5	“	42.5	“	14.4
Average	“	37.	“	42.	“	21.

The agreement is not very good, indicating that the garnet may contain still other molecules or that the assumption of a linear relation is incorrect. More probably, the agreement is poor because of the incorrect position of andradite on the diagram as previously mentioned. It should be noted that the percentages indicate a slight chemical dominance of spessartite over andradite although the size of the unit cube associates the garnet more closely with the grossularite-andradite group.

A few trials were also made on garnets consisting dominantly of only one constituent. In such cases the results were contradictory for the minor constituents due no doubt to inaccuracies in the plotted data. It might also be expected that these inaccuracies will make it difficult to obtain correct proportions between almandite and spessartite for these two garnets lie very close together on all of the diagrams.

Since, as previously shown, the discrepancies between observed and calculated specific gravities is fairly constant, the determination of the above garnets could be checked by determining the molecular weights from the chemical composition as found from the graphs, calculating the specific gravities and comparing the results with the observed values. If it were found that the calculated value was from .05 to .09 higher than the observed value this could be considered as a good check on the chemical composition as determined from the graphs. The calculated specific gravities of the above garnets are shown below in column I. The observed specific gravities are shown in column II. The differences are shown in column III.

	I	II	III
Garnet No. 4	4.075	4.018	.057
" " 22	4.130	4.1	.03
" " 14	4.090	4.01	.08
" " 30	3.935	3.900	.035

In each case the calculated value of the specific gravity is higher than the observed value. The differences for garnets No. 4 and No. 14 check with the expected differences. In the case of garnet No. 22 the difference is too low probably because the observed specific gravity is given only to one figure beyond the decimal place. In the case of garnet No. 30 the difference is too low probably because the position of andradite on the diagram is incorrect.

By this method it appears that the percentages of the dominant constituents, and sometimes even of a third minor constituent can be determined fairly accurately. The chief advantage of this method over one proposed by Ford is that no chemical analysis nor test (except for manganese) is necessary.

It is unfortunate that only a few chemically analyzed garnets have been studied. Before much confidence can be placed in quantitative determination by this method it will be necessary to test it out in many cases with material of known chemical composition. It is thought, however, that the general conclusions reached will stand. The chief usefulness of further work with analyzed material will be to test out the validity of the assumption that there is a linear relationship between size of unit cube and chemical composition.

This is only one of the many mineralogical problems which may be studied by X-ray analysis. The Department of Geology, University of Wisconsin, is anxious to obtain, for X-ray study, original material of analyzed garnets or any other minerals, and will be glad to take X-ray photographs and supply the contributor with all X-ray data on any analyzed material which may be sent here. Only a small quantity of material, about one-tenth of a cubic centimeter, is required for taking an X-ray photograph.

Table I. Properties of Certain Garnets

Dominant Molecule	No.	Index of Refraction	Specific Gravity	Edge of Unit Cube Å	Fe	Mn
Pyrope		1.705	3.510	11.430		
	1	1.752	3.777	11.44	present	absent
	2	1.745	3.750	11.48	present	absent
	3	1.742	3.686	11.504	present	absent
Almandite		1.830	4.250	11.493		
	4	1.784	4.018	11.47	present	absent
	5	1.818	4.085	11.49	present	absent
	6	1.804	4.10	11.49	present	absent
	7	1.807	4.071	11.501	present	absent
	8	1.792	4.060	11.50	present	absent
	9	1.8132	4.135	11.506		
	10	1.813	4.21	11.51	present	absent
	11	1.807	4.059	11.51	present	absent
	12	1.805	4.125	11.52	present	absent
	13	1.805	4.039	11.57	present	absent
	14	1.797	4.01	11.59	present	absent
Spessartite		1.800	4.180	11.568		
	15	1.815	4.166	11.54	present	present
	16	1.795	4.2	11.54	present	present
	17	1.820	4.173	11.55	present	present
	18	1.814	4.165	11.55	present	present
	19	1.805	4.20	11.55	present	present
	20	1.8057	4.169	11.562		
	21	1.810	4.189	11.57	present	present
	22	1.792	4.1	11.61	absent	present
	23	1.793		11.630	absent	present
Grossularite		1.735	3.530	11.840		
	24	1.760	3.620	11.79	present	absent
	25	1.745	3.582	11.80	little	absent
	26	1.738	3.588	11.82	little	absent
	27	1.742	3.558	11.826	absent	absent
	28	1.752	3.610	11.84	present	absent
	29	1.763	3.648	11.86	present	absent
Andradite		1.895	3.750	12.040		
	30	1.817	3.900	11.81	present	present
	31	1.835	3.887	11.84	present	present
	32	1.845	3.745	11.89	present	present
	33	>1.870	3.912	11.93	present	absent
	34	1.835		11.94	present	absent
	35	1.893	3.827	11.96	present	absent
	36	1.865	3.804	11.97	present	absent
	37	>1.870	3.811	12.00	present	absent
	38	>1.870	3.743	12.00	present	absent
	39	>1.870	3.826	12.02	present	absent
	40	1.897	3.770	12.029	present	absent

References for Table 1.

1. "Almandite" (pink), Waldheim, Granulitgeb, Saxony.
2. Pyrope (red), Navajo Reservation, Arizona.
3. Pyrope (red), Tribitz, Bohemia.
4. Almandite (red), Octzthal, Tyrol.
5. Almandite (red), Roxbury, Connecticut.
6. Almandite (red), Salida, Colorado.
7. Almandite (red), Fort Wrangel, Alaska. Ford's Analysis No. 13 was used in the calculation of the specific gravity.
8. Garnet (red), from a gneiss boulder in Wisconsin.
9. Almandite (red), Redding, Conn. For analysis, specific gravity and index see No. 18 of W. E. Ford.
10. Garnet (red), Shatford Lake, Manitoba. From contact metamorphosed andesite.
11. Almandite (red), Zillerthal, Tyrol.
12. Garnet (red), from andesite or graywacke. Winnipeg River, Manitoba.
13. Garnet (red), from arkosic schist, Meminiska Lake, Ontario.
14. Garnet (red), from amphibolite, Meminiska Lake, Ontario.
15. Garnet (red), from pegmatite, S. E. Manitoba.
16. Garnet (red), from lithia pegmatite, Winnipeg River, Manitoba.
17. Spessartite (red), U.S.N.M. No. 80457—Nathrop, Colorado.
18. Garnet (red), from pegmatite, S. E. Manitoba.
19. Garnet (red), from pegmatite, Cat Lake, Manitoba.
20. Spessartite (pink), Branchville, Conn. For analysis, specific gravity and index see No. 14 of W. E. Ford.
21. Garnet (red), from pegmatite, Winnipeg River, Manitoba.
22. Garnet (cream colored), from lithia pegmatite, Winnipeg River, Manitoba.
23. Spessartite (yellow), U.S.N.M. No. 80360. Llano Co., Texas.
24. Garnet (red), from metamorphosed limestone, Winnipeg River, Manitoba.
25. Grossularite (yellow), Santa Fé, N. M.
26. Grossularite (colorless), Ontario, Canada.
27. Grossularite (Roseolite) (pink), Xalostoc, Morelos, Mexico. The composition used in calculating the specific gravity is that given by Ford—No. 1.
28. Grossularite (Essonite) (light brown), Raymond, Maine.
29. Essonite (red), Essex Co., N. Y.
30. "Spessartite" (red), Haddam, Conn.
31. Polyadelphite (red), Franklin, New Jersey.
32. Andradite (Polyadelphite) (red), Franklin, N. J.
33. Andradite (Polyadelphite) (brown), Franklin Furnace, N. J.
34. Garnet (red), from highly metamorphosed limestone. Hedley, B. C.
35. "Grossularite" (brown), Morauitza, Banat.
36. Andradite (Melanite) (black), Franklin, N. J.
37. Andradite (yellowish), Ludwig, Lyon County, Nevada.
38. Garnet (brown), Texada Island, B. C.
39. "Grossularite" (brown), Vaskö, Hungary.
40. "Grossularite" (light green), Binnenthal, Switzerland.

THE MINERALS OF PRIBRAM

F. Slavík, *Prague.*

Among the old European metal mines, especially those of lead and silver, Příbram in Bohemia is one of the most famous, both from the mineralogical and technical as well as from the historical points of view. Not less interesting are the geological features of the Příbram region with its classical outcrops and fossil occurrences of the Cambrian (near Jince) and with its rich and variable development of Algonkian sediments and eruptives.

The city of Příbram, situated 82 kilometers southwest of Prague, is almost connected with the town of Březové Hory (=Birch Mounts), the center of the mining industry of to-day. Both Příbram and Březové Hory are located in Cambrian graywackes and sandstones which form a syncline underlain in the south-east Algonkian schists, beyond which the granite massive of cental Bohemia with its more basic differentiation products (quartz diorites, etc.), intrude and metamorphose the sediments.

In the north-west a great fault, called the Clay Fault (Jílová rozsedlina, Lettenkluft), separates the Cambrian formation from a second body of Algonkian schists over which again lie Cambrian conglomerates forming the mighty mountain chain of Brdy.

In general, the strata trend north-east and dip north-west except that portion of the Cambrian sediments along the Clay Fault, which form the northern wing of the synclinal cut off by the Fault. In this part where the dips are south-east and the beds are badly dislocated and are penetrated by numerous diabase dykes, the metalliferous veins are concentrated.

This briefly is the geological situation of the Příbram region, well known through the publications of Pošepný and his predecessors. Recently Mr. Kettner has made important contributions to the stratigraphy of the Cambrian formation and the tectonic features of this part of the Barrandien; his comprehensive paper on the geology of Příbram was published by the Czechoslovakian Geological Survey (vol. 5, 1925).

The metalliferous veins of Příbram accompany in most cases the diabase dykes, trending northerly with them and dipping almost vertically to the east. All principal veins lie in the "first graywacke" zone of Březové Hory; some veins however are of a different character and are included in the small quartz diorite massive of

Bohutín, south-west of Březové Hory, and in the Algonkian "second slate zone."

The vein filling at Příbram is very complicated and varies in different parts of the mining district and at different depths. The paragenesis of the Příbram veins has been studied by August E. Reuss[1] who discovered twenty-seven generations of minerals. An additional generation has been added by Adolf Hofman.[2] This list of succession is based on the observation of symmetrical development of the veins, which in Reuss' time was predominant in the whole district, in the upper horizons and to a depth of 650–700 meters. However at greater depths many of the veins become less interesting and the filling consists almost entirely of fine grained quartz with disseminated inclusions of sulphide ores; almost without a trace of symmetrical banding and with variable metallic values. This quartz filling is called at Příbram "krušek." In 1910 the late professor Adolf Hofman and the writer carried out a detailed microscopic study of the "krušek" of the mining district Březové Hory. The paragenesis and texture of the "krušek" seem to indicate a combination of four or five of the oldest members of Reuss' paragenetic series. The microscopical presence of cassiterite and the determination of diaphorite as the principal silver mineral in the "krušek" is interesting. We regard, therefore, the "krušeks" as those parts of the veins prevailing at depths where the entire opening has been filled with the oldest minerals and lacking the symmetrical banding caused by later depositions. Local changes produced various complications but the view that the "Krušek" fillings are an independent second generation of veins, younger than the symmetrical ones, is not supported by comparative observations in the new mine openings.

In the paragentic series of Reuss, Babánek and Hofmann, the following generations of minerals are enumerated:

1. Sphalerite I.
2. Galenite I.
3. Quartz I.
4. Siderite (all)

} Often alternating and grown together, sometimes with admixtures of minerals from the following (5) sequence.

5. Sulphide minerals and sulphosalts containing copper, lead, silver, arsenic and antimony; locally cobalt, nickel ores and cobaltiferous dolomite; uraninite, found very sparingly, also seems to belong to this period of formation.

---

[1] A. E. Reuss; *Sitzungsb. Akad. Wiss. Wien*, 1856 and 1863.

[2] Hofman and Slavik; *Rozpravy and Bull. international of the Czech Acad. of Sciences*, 1920.

6. Sphalerite II, apatite.
7. Barite I, gray large crystals of rectangular size with a dolomite crust.
8. Calcite I and pyrite I.
9. Calcite II.
10. Dolomite II.
11. Galenite II. (including so-called steinmannite, octahedral crystals with rounded corners).
12. Calcite III.
13. Pyrite II with younger sulphosalts (pyrargyrite, proustite, polybasite, pyrostilpnite), marcasite, pyrrhotite. Cronstedtite and lillite are alteration products.
14. Goethite ("velvet ore").
15. Calcite IV.
16. Quartz II.
17. Dolomite III.
18. Witherite.
19. Metallic silver (partly changed to argentite) and millerite.
20. Cerussite.
21. Smithsonite, hemimorphite, brown iron ore, psilomelane and pyrolusite.
22. Pyromorphite and campylite.
23. Wulfenite.
24. Barite II, transparent prismatic crystals with (102) dominant, of yellow and bluish colors.
25. Valentinite.
26. Calcite V.
27. Pyrite III.
28. Quite recent products of weathering include: malachite, xanthochroite, erythrite, annabergite, pharmacolite, zippeite; aragonite crusts on mine timber, formerly thought to be hydrozincite; gypsum.

Some of the minerals of Příbram, especially those found recently, are not included in this series because of their uncertain position, such as arsenic, antimony, allemontite, copper, hematite, kermesite and gummite; palygorskite.

Some doubts have been expressed as to the exactness of this detailed paragenetic list, and indeed it is hardly possible to prove for *every* mineral its place in the succession; some of the determinations, especially those in the second part of the series, have been based on isolated observations. The main features of the paragenesis, however, are remarkably constant in all Příbram veins, *e.g.* all siderite is older than all the other carbonates and we never find it among the younger oxide salts; the differences between the two generations of barite are very distinct, those between the five generations of calcite less so, but still discernible, etc. From a more genetic point of view there is no doubt but that this succession of minerals corresponds to stages of chemical deposition from solutions of decreasing temperatures, and that the metallic substances originated in the granitic magma of the Middle-Bohemian massive, as indicated also by the presence of some typically granitic-pneumatolytic minerals, cassiterite, scheelite, uraninite, etc.

In the earliest phases, the ore and gangue minerals of the first four or five numbers of Reuss' series were deposited almost contemporaneously, and therefore a more massive vein structure resulted, as in the "krušek." The following stage of vein filling is characterized by the presence of carbonates and the first generation of barite; among the sulphide minerals, sulphosalts are frequent. In this period undoubtedly ascending solutions were still the main sources for ore deposition and locally they changed their chemical character rather quickly, causing the well developed banded structure of the veins. In the third period (from Nos. 14 to 28 in Reuss' series), an intense oxidation of the sulphide minerals took place, and the native elements silver and copper were also formed. The genetic features of the oxydized minerals need further study to determine their relationsip to the older vein minerals and to the alteration products. It may be noted in passing that goethite (typical velvet ore) was found in 1918 at the 27th horizon, over 800 metres below the surface and that the beautiful crystals of the younger barite certainly can not be placed with the typical gossan minerals (numbers 20–22 of Reuss' series).

To the mineralogist Příbram is well known as the locality for numerous minerals, some of which are quite rare. Many of them have been found in magnificent specimens. The number of mineral species found at Příbram is over seventy. The following is a tabulated list.

(a) Native Elements

1. Arsenic } Allemontite has been shown to be an intimate mixture of
2. Antimony } arsenic and antimony.
3. Copper
4. Silver

(b) Sulphides and Sulphosalts

5. Stibnite, frequently in veins cutting the quartz diorite of Bohutín.
6. Sphalerite
7. Wurtzite, for which Příbram is the classical locality.
8. Xanthochroite
9. Niccolite
10. Millerite, very rare.

11. Pyrrhotite
12. Galena and so called steinmannite.
13. Argentite
14. Chalcocite
15. Pyrite (also in pseudomorphs after pyrrhotite and polybasite).
16. Smaltite
17. Chloanthite
18. Marcasite
19. Arsenopyrite
20. Löllingite—"leucopyrite"
21. Chalcopyrite
22. Bornite
23. Miargyrite
24. Berthièrite, at Bohutín with stibnite.
25. "Feather ores," described as boulangerite, to which most of the best specimens seem to belong; and jamesonite, the existence of which is, however, questioned because of the absence of basal cleavage.
26. Diaphorite, described for the first time from Příbram by von Zepharovich in 1871.
27. Proustite
28. Pyrargyrite, often very well crystalized.
29. Pyrostilpnite ("fire blende").
30. Bournonite, found to this day in large tabular twinned crystals of simple combinations.
31. Tetrahedrite, argentiferous.
32. Stephanite, classical material of Vrba's monograph.
33. Polybasite
34. Stannite, only microscopic inclusions in galena.
35. Kermesite

(c) OXYDES

36. Valentinite, rare and at present exhausted.
37. Quartz
38. Cassiterite, only microscopic in the "krušek".
39. Pyrolusite, principally at Narysov, S. W. from Příbram.
40. Uraninite, found locally.
41. Hematite, subordinate.
42. Goethite, mostly as spherules with a finely fibrous structure ("velvet ore").
43. Brown iron ore
44. Psilomelane
45. Wad

(d) CARBONATES

46. Calcite
47. Dolomite
48. Siderite -
49. Smithsonite
50. Aragonite
51. Witherite, very rare, at Bohutín.

52. Cerussite in numerous forms, commonly in twins.
53. Malachite
54. Azurite

(e) SULPHATES, ETC.

55. Barite in two generations (see above).
56. Scheelite, found only once in very few specimens.
57. Wulfenite, in gray prismatic and tabular crystals, formerly more frequent.
58. Gypsum
59. Zippeite alteration product of uraninite

(f) PHOSPHATES AND ARSENATES

60. Apatite, almost colorless, in tabular crystals, rare.
61. Pyromorphite, one of the most frequent gossan minerals.
62. Campylite
63. Mimetite
64. Vivianite, accidentally formed on bones in an abandoned mine at Bohutín.
65. Erythrite
66. Annabergite
67. Pharmacolite
68. Pitticite.

(g) SILICATES

69. Hemimorphite
70. Palygorskite (xylotile)
71. Cronstedtite, first described in 1820 from Příbram and known from very few other localities.
73. Lillite, imperfectly known leptochloritic mineral, found at Příbram, as an alteration product of pyrite, associated with "velvet ore."
74. Kaolinite
75. Gummite, rare alteration product of uraninite.

Outside of the veins, as secondary minerals in diabase, epidote, chabazite, harmotome and desmine have been found.

A beautiful collection of Příbram minerals and vein specimens are exhibited in the National Museum at Prague; and in the Mining Directory and High School in Příbram.

While the story of the mining at Příbram dates from the 14th century it was not until the beginning of the 16th century that the mines were extensively worked. In 1875, the Adalbert mine was the only mine in the world reaching a depth of 1000 meters. Actually, the mine workings are limited to the central part of the "first graywacke zone" at Březové Hory and to a less extent, to the quartz diorite of Bohutín. All mines are State possessions.

The Mining High School was founded in 1849; the Mineralogical Laboratory was united with the Geological Department until 1920. Among the numerous professors who have been connected with this school, Professor František Pošepny is perhaps the best known.

THE RELATION OF FRENCH AND AMERICAN GRÜNERITES TO SIMILAR FERRO-MANGANESE AMPHIBOLES OF SWEDEN

STEPHEN RICHARZ, *Techny, Illinois.*

In recent years several attempts have been made to arrange in a series the characteristics of non-aluminous amphiboles. Sundius[1] and Winchell[2] succeeded fairly well in representing refraction, birefringence and specific gravity as a continuous function of the molecular percentages of iron and manganese. Unfortunately, the properties of Lake Superior grünerite, an important link in this series was hitherto practically unknown. A reëxamination of this amphibole[3] revealed new aspects which seem worth while to be taken into consideration.

Neglecting other constituents, Sundius calculated the molecular percentages of $FeSiO_3$, $MnSiO_3$, and of $MgSiO_3$, the $FeSiO_3$ containing also a small amount of ferric iron. Those values which refer to ferro-manganese amphiboles are reproduced from his table on page 163, retaining his numeration; to these amphiboles are added the respective data of French and American grünerites.

	$FeSiO_3$	$MnSiO_3$	$MgSiO_3$	α	β	γ	$\gamma-\alpha$	sp. gr.
6	40.83	14.76	44.41	1.650	(1.665)	1.679	0.029	3.311
5	47.26	16.00	36.73	1.650	(1.670)	1.695	0.035	3.34
4	60.88	11.66	27.64	1.663	(1.684)	1.699	0.036	3.396
3	66.55	14.35	19.10	1.6696	1.6904	1.7057	0.036	3.446
2	69.71	20.63	9.66	1.673	(1.697)	1.713	0.040	3.516
I	83.57	1.39	15.04	1.666	1.684	1.700	0.034	3.44
II	90.38	0.16	9.46	1.672	1.697	1.717	0.045	3.518
III	96.37	—	3.63	(1.696)	(1.7415)	(1.752)	0.056	3.713

(6) Ö. Silvergruvan, (5) Brunsjögruvan, (4) Stromshult, (3) V. Silvberg, (2) Dannemora, (I) Mt. Humboldt, Michigan, (II) La Malières, near Collobrières (Kreutz), (III) Collobrières (Grüner and Lacroix).

The indices within parentheses are calculated. Of the original French grünerite, analyzed by Grüner, only $N = 1.73$ (indice médian) is given by Michel Lévy and Lacroix (Minéraux des roches, 2, 147) which equals $\alpha+\beta+\gamma/3$. From this N and from the negative optical angle 2V = 50°, the indices given above were calculated. Of course, they have only an approximate value, until exact measurements become available.

---

[1] Nils Sundius; Zur Kenntnis der monoklinen Ca-armen Amphibole (Grünerit-Cummingtonit-Reihe), *Geol. För. Förh., Stockholm,* **46,** p. 154 (1924).

[2] A. N. Winchell; The $FeSiO_3$-$CaSiO_3$-$MgSiO_3$-$NaFeSi_2O_6$ system of monoclinic amphiboles, *Am. Mineral.,* **10,** p. 335 (1925).

[3] Stephen Richarz; The amphibole grünerite of the Lake Superior region, *Am. J. Sci.,* **14,** (fifth series), 150 (1927).

Combining $FeSiO_3$ and $MnSiO_3$ and plotting this sum against $MgSiO_3$, the optical data and the specific gravity of the above table result in the following figure.

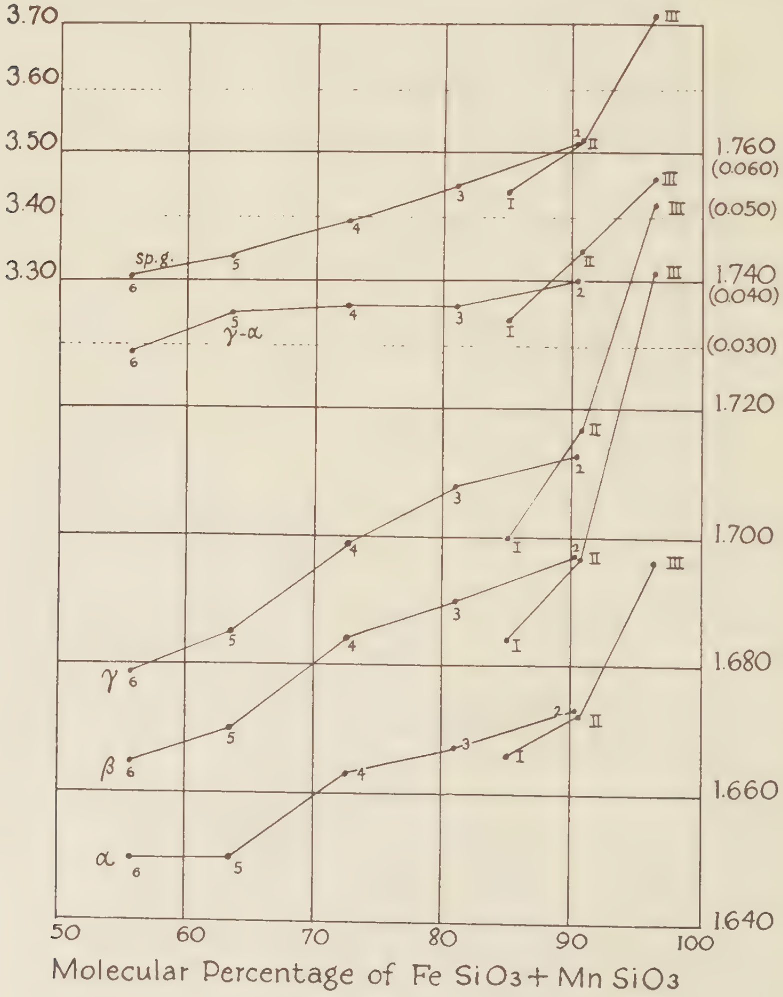


FIG. 1.

It is evident from this diagram that the original grünerite and its American variety do not form a continuous series with the ferro-manganese amphiboles of Sweden. Apparently, the high amount of MnO affects the optical constants in quite a different manner than the high percentage of ferrous iron influences the refractive indices of grünerite. The indices of Lake Superior grünerites which contain 85% $FeSiO_3+MnSiO_3$, are about as low as those of the ferro-manganese amphibole number 4 with only $72\frac{1}{2}$%, the birefringence is even lower. However, with the increase of iron in the French grünerites, refraction and double refraction mount rapidly. On account of these differences it would be more appropriate, to reserve the name grünerite for those ferrous amphiboles, in which the amount of manganese is negligible, and to apply the name "Dannemorite" to the ferro-manganese varieties, as was proposed by Palmgren.[4]

There seems to be a growing tendency to disregard Grüner's and Lacroix' original data on grünerite from Collobrières. After the thorough reëxamination of grünerite from the same or a neighboring locality by Kreutz, there is no good reason to reject the work done by the former investigators, although the analysis is incomplete and the optical properties need to be checked by modern methods. We are certainly justified in assuming that Grüner and Lacroix studied a different variety of grünerite than Kreutz, one which was richer in iron and poorer in magnesia; the optical characteristics are in fair agreement with this change in chemical composition. It is to be hoped that the French mineralogists in the near future restudy the material collected at various localities in the vicinity of Collobrières, both chemically and optically. As far as macroscopical appearance is concerned, the variability of the grünerite from Collobrières may be inferred from the following. Lacroix describes in a later publication the fibers of grünérite as olive-green ("des fibres souvent rayonnées de grünérite d'un vert olivâtre, à éclat vif.)[5] My friend, Professor Kreutz, was kind enough to send me a sample of the grünerite which he investigated. These fibers are colorless to pure white with a silky luster. This difference in color suggests a difference in chemical composition and consequently in the optical characteristics.

---

[4] "Es scheint mir das beste, den Namen Dannemorit als den ältesten beizubehalten, und unter diesem Namen zukünftig die manganhaltigen Varietäten des Grünerit zusammenzufassen." John Palmgren; Die Eulysite von Södermanland, *Bull. Geol. Inst. Univ. Upsala,* **14,** 161 (1916–1917).

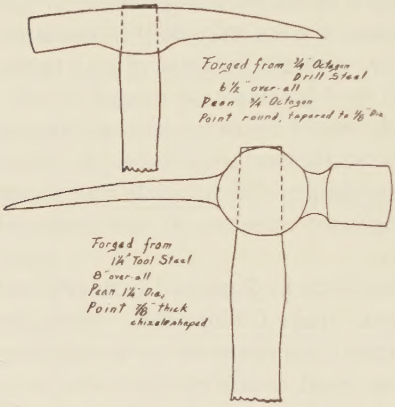
[5] A. Lacroix; Sur une roche de fayalite; *Comptes rendus de l'Acad. des Sci.,* **130,** 1778 (1900).

NOTES AND NEWS

GEOLOGICAL HAMMERS

Gilbert Hart, *Birmingham, Alabama.*

Most geological hammers are of a pattern modified from the stone-mason's hammer, made with short square ends, and to be used more for chipping than for breaking. The two hammers sketched were made by ordinary black-smiths, of common drill-steel, and have been found to serve the purpose of breaking rock much more effectively than the orthodox pattern. The smaller one is light enough to be carried all day without any fatigue, and yet it is heavy enough to be constantly used. The larger one is very well adapted for collecting in one locality, the wide chisel edge being especially useful in prying up shale ledges, or in cleaving massive minerals.


Forged from 3/4" Octagon Drill Steel
6 1/2" over-all
Pean 3/4" Octagon
Point round, tapered to 1/8" Dia
Forged from 1 1/4" Tool Steel
8" over-all
Pean 1 1/4" Dia,
Point 7/8" thick chizel shaped

One essential feature is the "adze-eye," the widening of the steel at the eye; which adds greatly to the life of the hammer. The pean end should be crowned, so that a clean true blow can be given without danger of sharp edges developing fractures thru the specimen. Hammers should be well tempered, so that they will resist the abrasion of use, yet not be brittle and easily broken.

NOTES ON MINERALS FROM THE BEDFORD, N. Y., WESTCHESTER CO. QUARRY.

Samuel C. Brown, *Stamford, Connecticut.*

The writer has collected at this quarry the following minerals: Thin tabular specimens of *ilmenite*, associated with massive manganese garnets and quartz. *Columbite*, fairly well developed crystals, more brittle and less iridescent than the specimens obtained at Branchvill, Connecticut. Small scales of *autunite* on *uraninite* with zircon (massive), found in the North Quarry. The uraninite is not plentiful; also traces of autunite have been found on microcline. *Iron Pyrites* with a ferruginous coating, small crystals associated with partly disintegrated microcline. Green and blue *beryls* in large crystals are found, but not of gem quality. It has been reported that a few golden beryls have also been recovered. Black *tourmalines* are plentiful, but there are very few with perfect terminations; they are found with quartz as a matrix. *Rose quartz* of fine, deep color, somewhat opalescent is found abundantly. Likewise *black massive quartz* that is decidedly opaque, in fact, the finest the writer has ever seen. *Quartz crystals* of peculiar habit in parallel position and with the appearance of formation under pressure, are obtained near the contact of the red microcline with the quartz. *Muscovite* has been obtained in the South Quarry; thin sections of the sheets show very distinct outlines of magnetite.

NOMINATIONS FOR OFFICERS OF THE MINERALOGICAL SOCIETY FOR 1928.

The unanimous nominations of the Council for officers of The Mineralogical Society of America for 1928 are as follows:

President, Esper S. Larsen, Harvard University, Cambridge, Massachusetts.
Vice-President, Lazard Cahn, Colorado Springs, Colorado.
Secretary, Frank R. Van Horn, Case School of Applied Science, Cleveland, Ohio.
Treasurer, Alexander H. Phillips, Princeton University, Princeton, New Jersey.
Editor, Walter F. Hunt, University of Michigan, Ann Arbor, Michigan.
Councilor, 1928–1931, Ellis Thomson, University of Toronto, Toronto, Canada.

The eighth annual meeting of the Society will be held December 29–31, 1927, at Western Reserve and Case School of Applied Science, Cleveland, Ohio. It is planned to publish in the December issue of the Journal a *preliminary* list of titles of papers to be presented before the Society at its annual meeting. In order to appear on the advance program, titles of papers should be in the hands of the Secretary by *November 10.*

Frank R. Van Horn, *Secretary.*

NEW MINERAL NAMES

Arrojadite

Djalma Guimarães: Arrojadita, um novo mineral do grupo da wagnerita. (Arrojadite, a new mineral of the wagnerite group). *Publicação da Inspectoria de Obras Contra as Seccas*, Rio de Janeiro. No. 58, **1925**.

Chemical Properties: A phosphate of iron, manganese and other bases. Formula: $4R'_3PO_4 \cdot 9R''_3P_2O_8$. Analysis: P_2O_5 34.32, Fe_2O_3 12.39, FeO 19.84, MnO 12.33, CaO 5.69, MgO 1.85, Na_2O 4.67, K_2O 1.45, Li_2O tr., H_2O (110°) 0.44, H_2O (over 110°) 4.96, SiO_2 0.66, SnO_2 1.52; total 100.12. (Sample contained some hematite, quartz, cassiterite and some alteration products along the cleavages).

Crystallographic Properties: Monoclinic. Cleavage perfect.

Physical and Optical Properties: Color dark green. Pleochroic. $X = Y =$ colorless, $Z =$ pale green. Biaxial, negative. $2V = 71°$. $\gamma = 1.70$. $\gamma - \alpha = 0.007$. $H =$ slightly over 5.

Occurrence: Found massive at Serro Branco, Picuhy, Parahybla, Brazil. Believed to be the same as dark green phosphate described by W. P. Headden from South Dakota (Dana p. 758).

W. F. Foshag

Ianthinite

Alfred Schoep: Over janthiniet, een nieuw uranium mineral uit Katanga. (On Ianthinite, a new uranium mineral from Katanga). *Natuurwetenschappetijk Tijdschrift, Antwerpen,* **7,** pp. 97–99 (1926). (*Mineral. Abs.,* **3,** 232, 1927). Nouvelles observations sur l'Ianthinite. *Ann. Soc. Geol. Belg.,* **49,** 310–313, 1927).

Name: From the Greek (*ianthinos*) violet colored.

Chemical Properties: Contains water, uranium and iron. Ignition loss (perhaps some gain in oxygen) 15.85. Believed to be $2\ UO_2 \cdot 7\ H_2O$. In the second paper the residue after ignition is said to be apparently all uranium.

Crystallographic Properties: Orthorhombic. Acicular crystals. Angle between terminal faces 62° (supplementary angle). Cleavage, micaceous, (100).

Physical and Optical Properties: Color, violet black, altering on the edges to yellow; streak, brown violet. Luster, semi-metallic. Bi-axial negative. Extinction parallel. Plane of the optic axes across the needles; Bx_a perpendicular to (100). $\alpha=1.674$, $\beta=1.90$, $\gamma=1.92$. Pleochroism strong: *a* colorless, *b* dark violet, *c* violet.

Occurrence: Found in cavities in a specimen of uraninite from Kasola, Belgian Congo, associated with becquerélite and schoepite.

Discussion: Alters upon heating with dilute hydrogen peroxide, turning brown then yellow and shows the following properties: Biaxial positive. Plane of the optic axes parallel to the elongation. $\beta=1.61$ (approx.). This product is neither schoepite nor becquerélite. W.F.F.

Eschwegeite

Djalma Guimarães: Echwegeita, Novo Mineral encontrado em Minas Geraes. (Eschwegeite, a New Mineral found in Minas Geraes). *Bol. Inst. Sci. Brazil*, **2,** 1–2 (1926).

Name: In honor of Baron W. L. *Eschwege.*

Chemical Properties: A hydrous titanate, columbate and tantalate of yttrium and erbium. Formula, $5\ Y_2O_3\cdot 6\ (Ta, Cb)_2O_5\cdot 10\ TiO_2\cdot 7\ H_2O$. Analysis: Ta_2O_5 21.58, Nb_2O_5 25.17, TiO_2 18.75, $(Y, Er)_2O_3$ 27.28, ThO_2 0.57, UO_2 1.96, Fe_2O_3 2.05, H_2O 3.09. Sum 100.45.

Physical and Optical Properties: Color, dark reddish gray; dark red in thin splinters. Fracture conchoidal. H. 5.5. Sp. Gr. 5.87. Isotropic, *n* between 2.15–2.20.

Occurrence: Found as pebbles in the Upper Rio Doce, Minas Geraes. Resembles rutile. W.F.F.

Korea-augite

Fujimaro Yamanari: Soda-pyroxenes in the Tertiary and post-Tertiary alkaline rocks from the environs of the Sea of Japan. *Jap. Jour. Geol.*, **III,** 105–107 (1924). Also Koto *Commemoration Volume*, 105, 111 (1925).

Name: An *augite* from *Korea.*

Chemical Properties: A soda-pyroxene.

Optical Properties: Color in thin section green without much pleochroism, when thin X=Y light yellow to greenish yellow, Z golden yellow. $Y=b$, $Z\wedge c=10°$ in acute β. Birefringence moderate.

Occurrence: As phenocrysts or small rods in the "hakutolite" (acidic alkali-trachyte) at Tonghodong, Musēn, North Kankyō-dō, Korea. W.F.F.

Trachyaugite

Ibid.

Name: An *augite* from *trachyte.*

Chemical Properties: A soda-pyroxene.

Optical Properties: Color black, in thin section bluish-green to yellowish green, birefringence high. $Y=b$, $Z\wedge c=44°$.

Occurrence: As phenocrysts or minute rods in alkali-trachytes and phonolites from Circum-Japan Sea Region, especially at Oki Islands and Utsuryō Island.

W.F.F.